U.S. Army Research, Development and Engineering Command

Adaptive Computer-based Tutoring in an ADL Context

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Agenda

- Intro to Intelligent Tutoring Systems (ITS) - Bob
- Tutoring Research Highlights – Bob
- Vision for ITS in ADL 2025 - Bob
- Technical Foundations of ITS - Scott
- ITS in Service Oriented Architectures - Scott
- Vision for ITS in ADL 2025 - Scott

Distributed Learning meets Computer-based Tutoring

- **U.S. Military is deployed worldwide on a consistent basis so training technology should be:**
  - **accessible wherever the Soldier is located and whenever they need training**
  - **interactive regardless of infrastructure available**
  - **intelligent so it can be used in the absence of human instructors**

- **The time allotted for training is limited so training should be:**
  - **efficient as well as effective**
  - **engaging, challenging and relevant to the Soldier's mission**
  - **adaptive to the trainee's needs and capabilities**

Grand Challenges for Educational Technology

- **Personalize Education**
- **Assess Student Learning**
- **Support Social Learning**
- Diminish Boundaries
- Develop Alternative Teaching Methods
- Enhance the Role of Stakeholders
- Address Policy Changes

Do computer-based tutors support these goals?
Does ADL support these goals?

Woolf, B. P. (2010). *A Roadmap for Education Technology. National Science Foundation # 0637190*

The Tutoring Process

- **Problem Selection**
  - selection based on student's knowledge, understanding of the material and motivational state
- **Problem Presentation**
  - tutor informs student about problem; encourages and motivates
- **Problem Solution**
  - student attempts to solve problem; tutor provides feedback appropriate to their competence
- **Reflection**
  - once problem is solved, tutor encourages student to consider process, methods and relationship to other contexts
- **Instruction**
  - additional information about concepts and remediation as needed

Lepper, M. and Woolverton, M. (2002). The Wisdom of Practice: Lessons Learned from the Study of Highly Effective Tutors. In J. Aronson (Ed) *Improving academic achievement: impact of psychological factors on education* (pp. 135-158). New York: Academic Press.

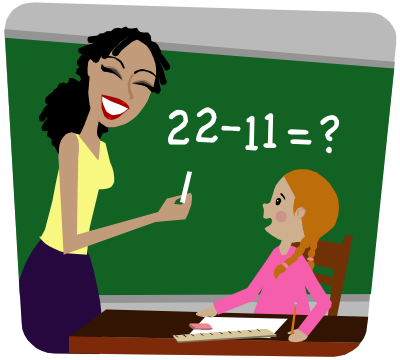
INSPIRE Model of Tutoring Success

- **Intelligent** – credible
- **Nurturing** – supportive
- **Socratic** – questions, not directions; hints not answers
- **Progressive** – planned, structured and systematic
- **Indirect** – avoid overt criticism; less explicit or profuse positive feedback
- **Reflective** – ask students to discuss process, explain answers and generalize problem to other domains
- **Encouraging** – bolster confidence; challenge students; pique curiosity

Lepper, M. R., Drake, M., & O'Donnell-Johnson, T. M. (1997). Scaffolding techniques of expert human tutors. In K. Hogan & M. Pressley (Eds), *Scaffolding student learning: Instructional approaches and issues* (pp. 108-144). New York: Brookline Books.

Human Tutoring Topologies

One-to-One (Private Tutoring)



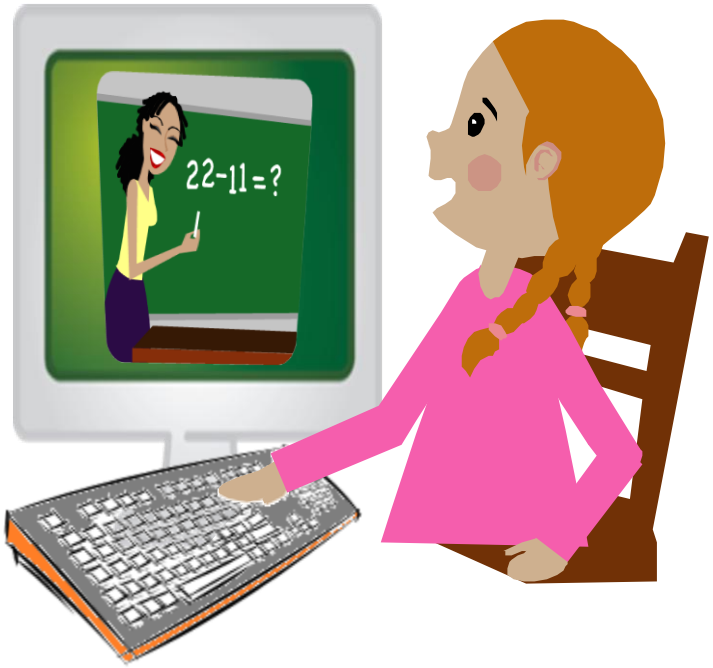
One-to-Many (Traditional Classroom)

Students who work one-to-one with expert human tutors often score 2.0 standard deviations higher than students in a conventional classroom (Bloom, 1984)

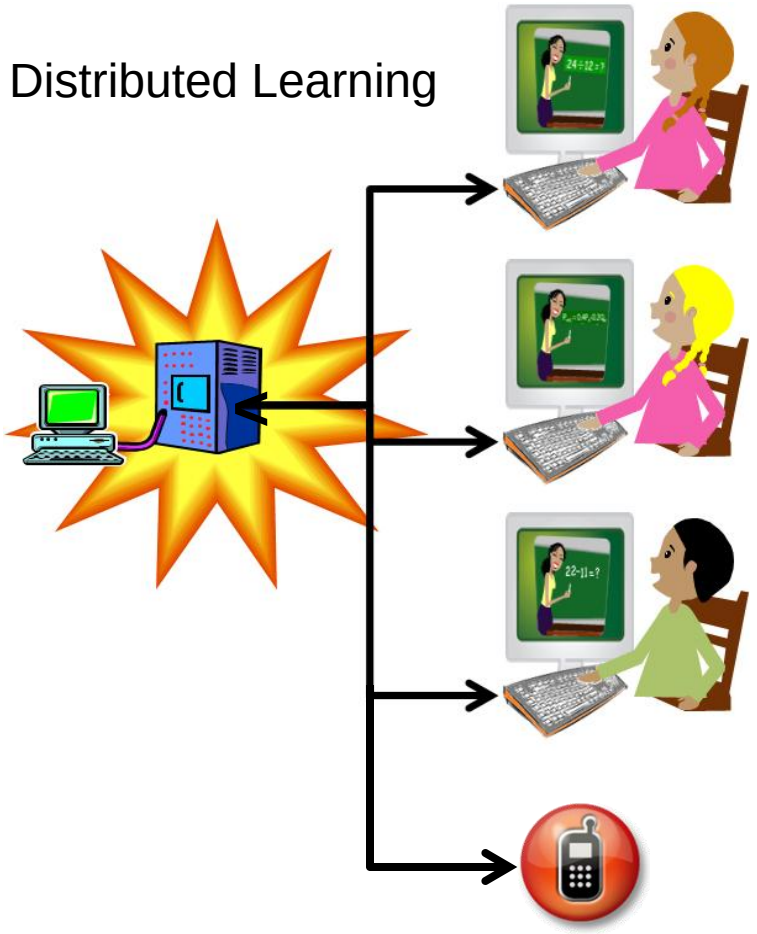
Bloom, Benjamin S. (1984) The 2-sigma problem: The search for methods of group instruction as effective as one-to-one tutoring, Educational Researcher 13: 4-16.

Computer-Based Individual Tutoring Topologies

One-to-One (Private Tutoring)



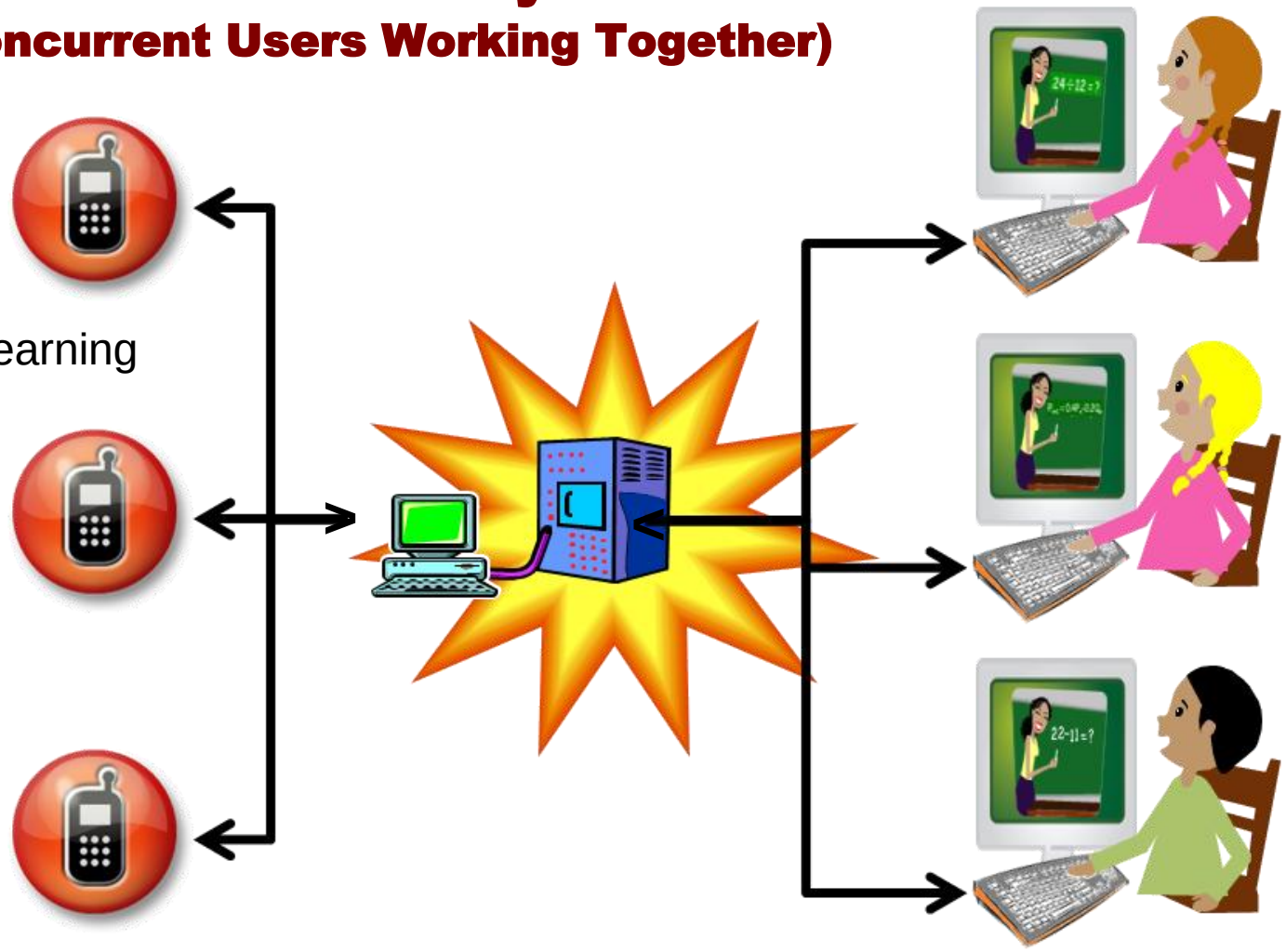
One-to-Many (Concurrent Users Working Separately, Asynchronously)



Computer-Based Team Tutoring Topologies

One-to-Many
(Concurrent Users Working Together)

Mobile Learning



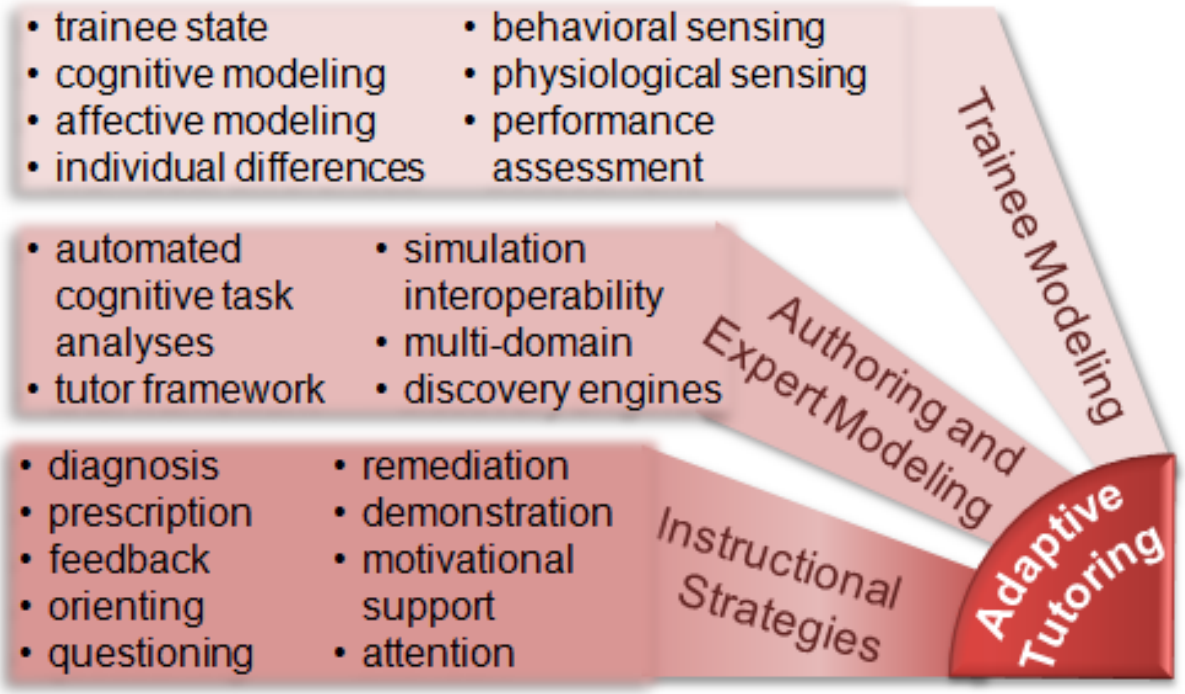
Computer-Based Tutoring Taxonomy

Assess → Model → Predict → Adapt → Influence Learning

understand individual trainee learning needs

make tutors & models easy to create and use

use trainee state & learning context to select appropriate strategies

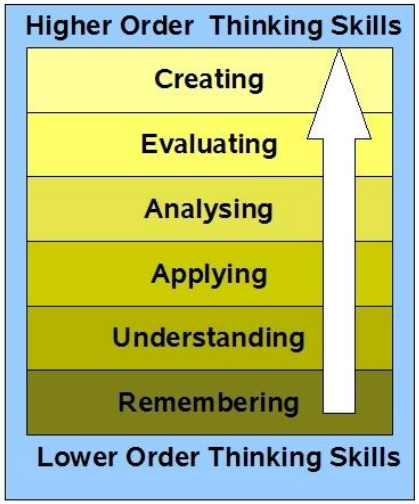


Goals for Adaptive Tutoring

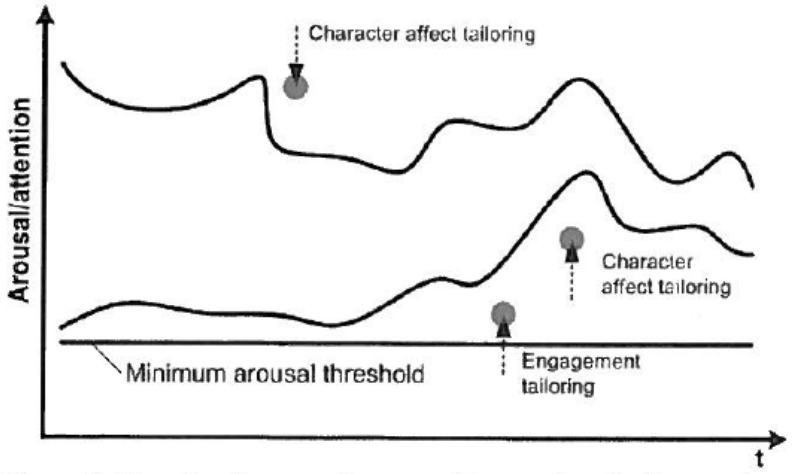
Assess → Model → Predict → Adapt → Influence Learning

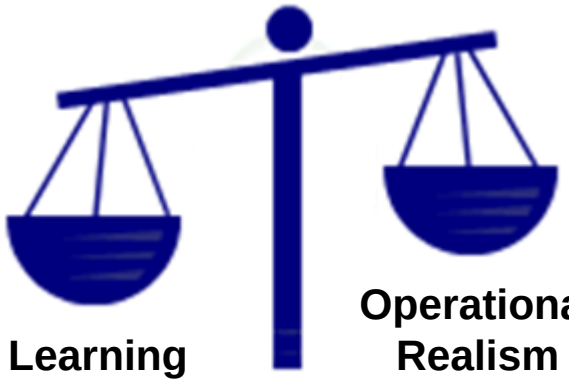
- **low-cost, passive sensing of trainee physiology and behaviors**
- **near real-time classification of trainee cognition and affect**
- **near real-time classification of optimal instructional strategies based on:**
  - **cognition (attention, engagement…)**
  - **affect (personality, mood, emotions)**
  - **historical trainee data (competence, preferences…)**
- **automated authoring**
  - **student modeling**
  - **expert modeling**

Cognition and Affect



Assessing cognition and affect during training is on the critical path of adapting training to Soldiers' individual differences





Tutoring Research Questions

Assess → Model → Predict → Adapt → Influence Learning

- **General:** How can computer-based tutoring technologies **accelerate learning and facilitate retention** in distributed environments?

- **Learner Modeling:**
  - How should a learner's **individual differences be used by tutors** to influence learning and retention?
  - Which individual differences have the **most significant impact** on learning?
  - Which classification methods are most accurate for determining the learner's cognitive and affective states?

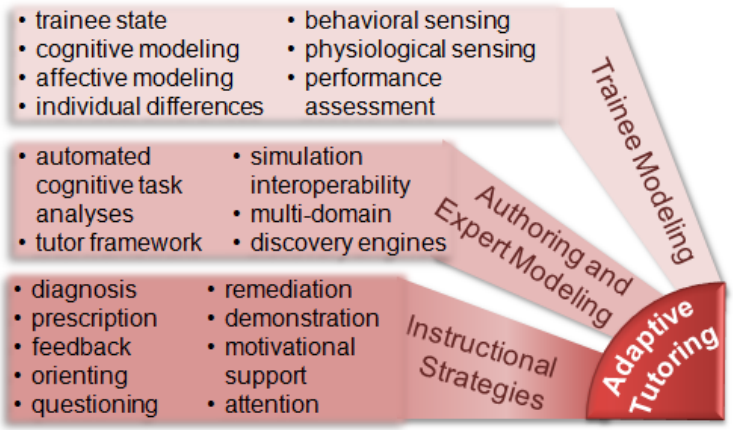
- **Authoring and Expert Modeling:**
  - Which frameworks, tools and methods are making tutors **easier to develop, assess, deploy and use**?

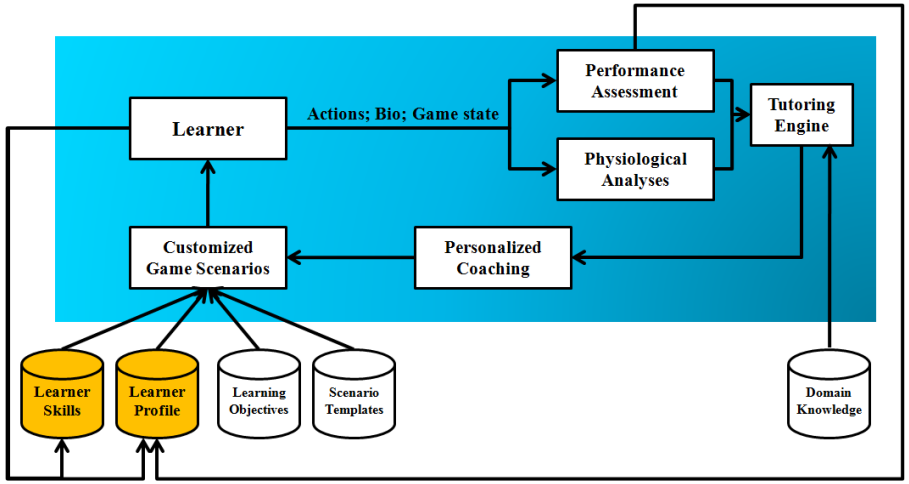
- **Instructional Strategy Selection:**
  - Which instructional strategies are optimal for learning and retention given the learner's state (cognitive, affective) and the learning context?
  - Which instructional strategy selection methods are most consistent in selecting strategies that are optimal for the learner's state and learning context?

Adaptive Computer-Based Tutoring

Conceptual → Practical → Ubiquitous

Taxonomy





Research & Development

1. Adaptive Tutoring Research
2. Generalized Intelligent Framework for Tutoring (GIFT)

Technology Areas of Interest

A. Trainee Modeling – Improve methods to determine learner's cognitive and affective states in real-time

B. Instructional Strategy Selection – Improved methods to optimize instruction based on trainee's state

C. Authoring – automated processes to enhance interoperability of tutors with training simulations

D. Authoring – automated processes to: build models and content; test tutoring concepts; and reduce development/support costs

Trainee Modeling

TRAINEE MODELING

- Low-cost behavioral and physiological sensors
- Predictive cognitive and affective modeling
- Trainee modeling to inform instructional strategy decisions
- Assessment of the influence of individual differences

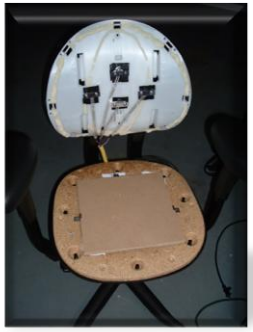
Innovative machine modeling techniques

Cognitive & affective state models for teams

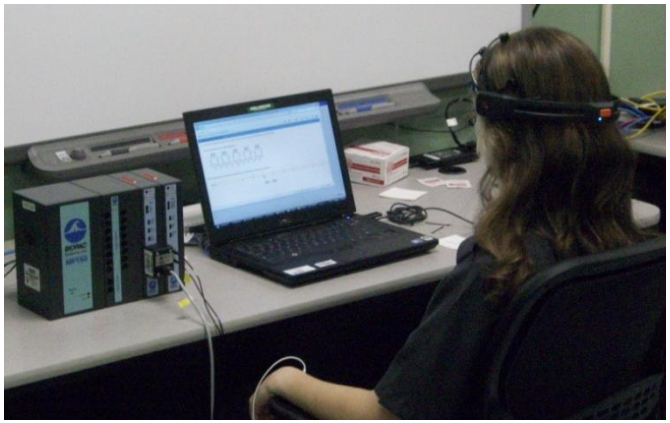
Unobtrusive, real-time individual and team modeling technologies

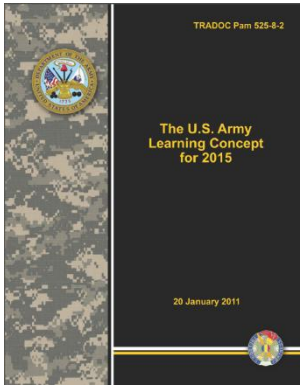
PAYOFFS – SUPPORT SELF-DIRECTED LEARNING & CONTINUOUS ADAPTIVE LEARNING MODEL (ALC 2015)

- Improved understanding of trainee's "readiness to learn"
  - cognition – thinking skills
  - affect – motivation and commitment to learning
- Tailored, optimal instructional decisions by tutors
- Integrated, historical perspective of trainee performance
- More effective computer-based tutors/coaches
  - improved trainee performance
  - improved trainee knowledge



unobtrusive sensing





Authoring and Expert Modeling

Generalized Intelligent Framework for Tutoring (GIFT)

Game-Tutor Standardized Interface

Discovery engines to model individual expert behaviors

Human-Tutor Interaction Design

Innovative expert modeling techniques

Discovery engines to model expert teams

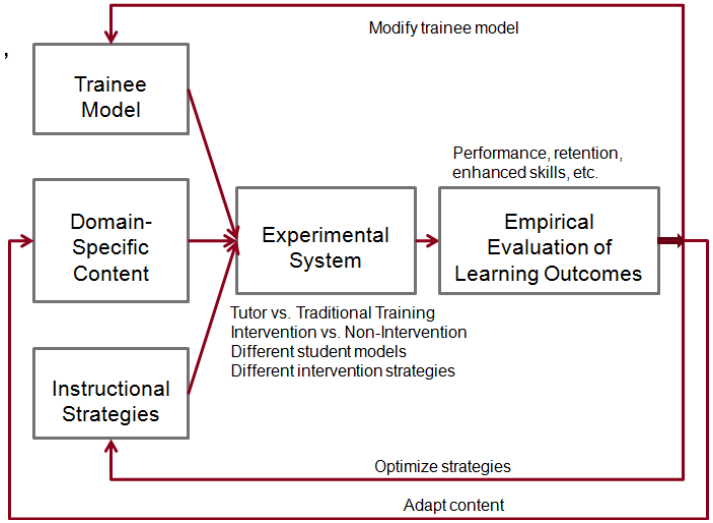
Fully automated intelligent authoring tools for tutors

PAYOFFS – REDUCED TUTOR DEVELOPMENT COSTS AND USABILITY

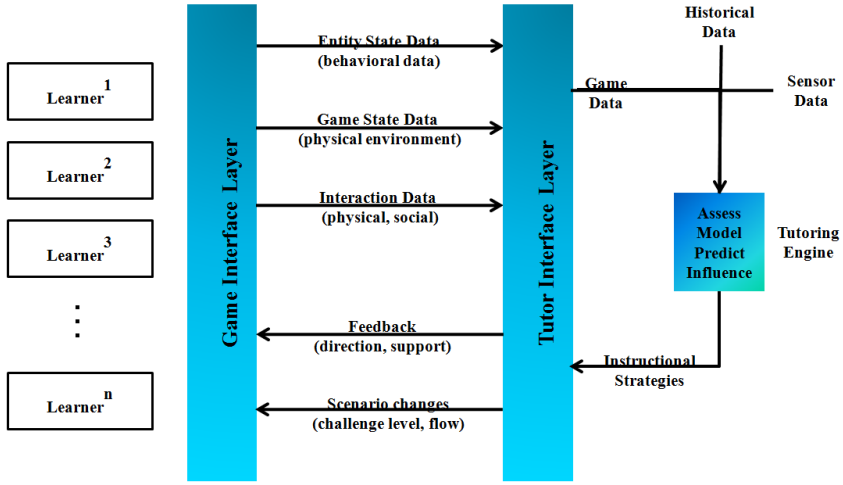
- Standard architecture (GIFT) for tutor R&D
  - test new concepts and models
  - develop tutoring content and models
  - develop standards for integration with training sims
  - domain-independent approach

GIFT

- Reduced cost for tutor integration with game-based training
- Reduced cost to develop expert models for individuals & teams
- Improve usability of tools for domain experts (e.g., trainers)
  - enhanced automation



Methodology derived from:
Hanks, S., Pollack, M.E. and Cohen, P.R. (1993). Benchmarks, Test Beds, Controlled Experimentation, and the Design of Agent Architectures. AI Magazine Volume 14 Number 4.



Sottilare, R. and Gilbert, S. (2011). Considerations for tutoring, cognitive modeling, authoring and interaction design in serious games. *Authoring Simulation and Game-based Intelligent Tutoring workshop at the Artificial Intelligence in Education Conference (AIED) 2011*, Auckland, New Zealand, June 2011.

Instructional Strategy Selection

- Strategy selection models based on trainee state
- Learning strategies tailored to training objectives
- Strategy selection to optimize learning and retention
- Macro and micro-adaptation
- Scaffolding

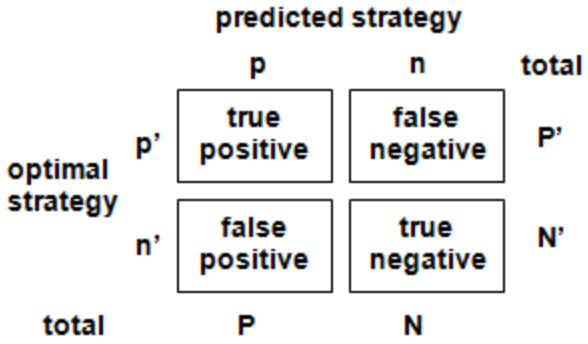
- Innovative machine decision techniques
- Strategy selection models based on team state
- Adaptive instruction in ill-defined domains

Adaptive, career-long learning companion to inform instruction

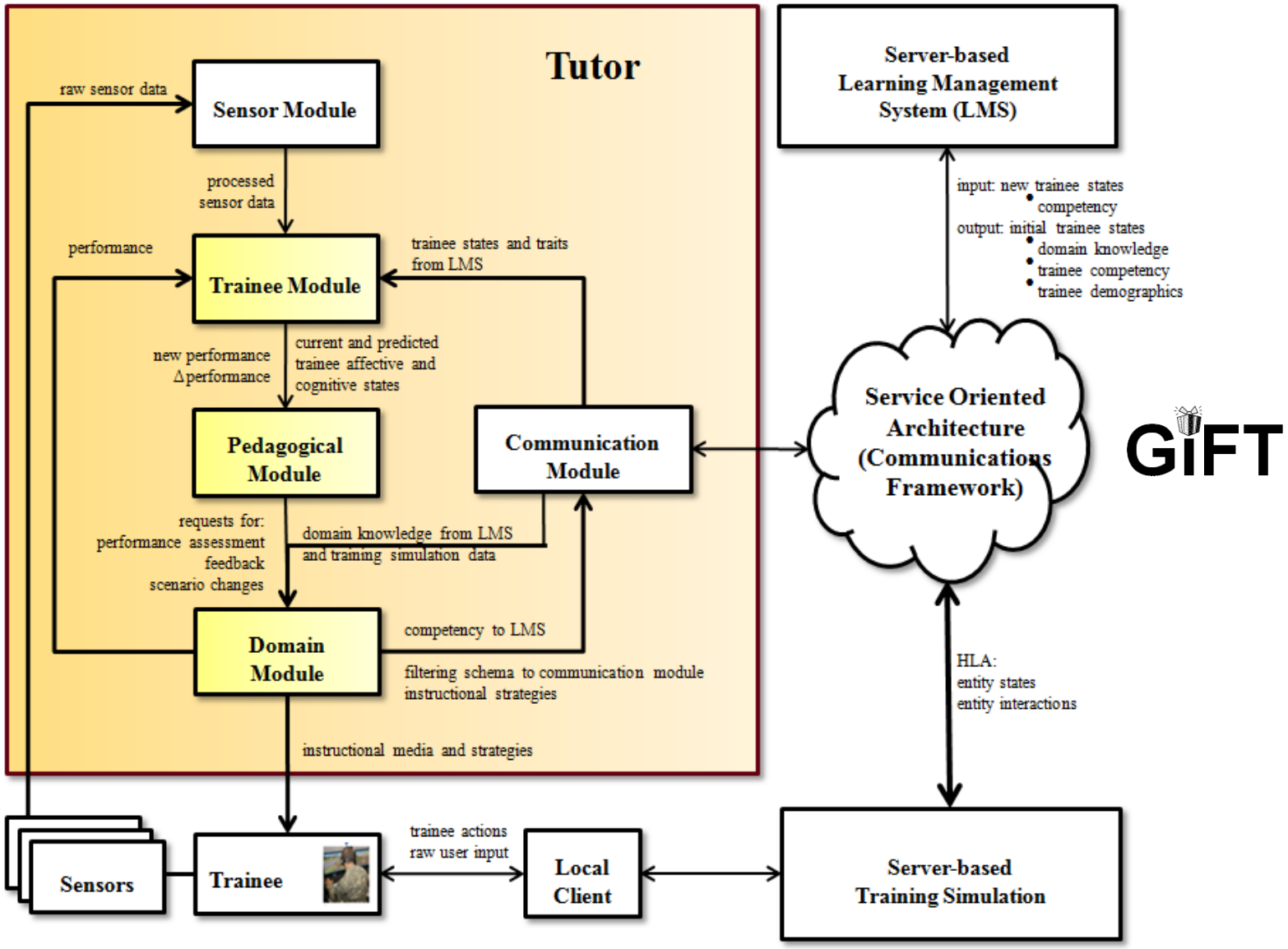
PAYOFFS – EFFICIENT AND EFFECTIVE COMPUTER-BASED TUTORING

- Efficient tutoring processes
  - content and feedback tailored to trainee needs
  - adaptive challenge-level and flow of instruction
- Effective tutoring processes
  - content selection appropriate to trainee competency
  - validated strategies for use across:
    - well-define and ill-defined domains
    - simple and complex tasks
    - various populations

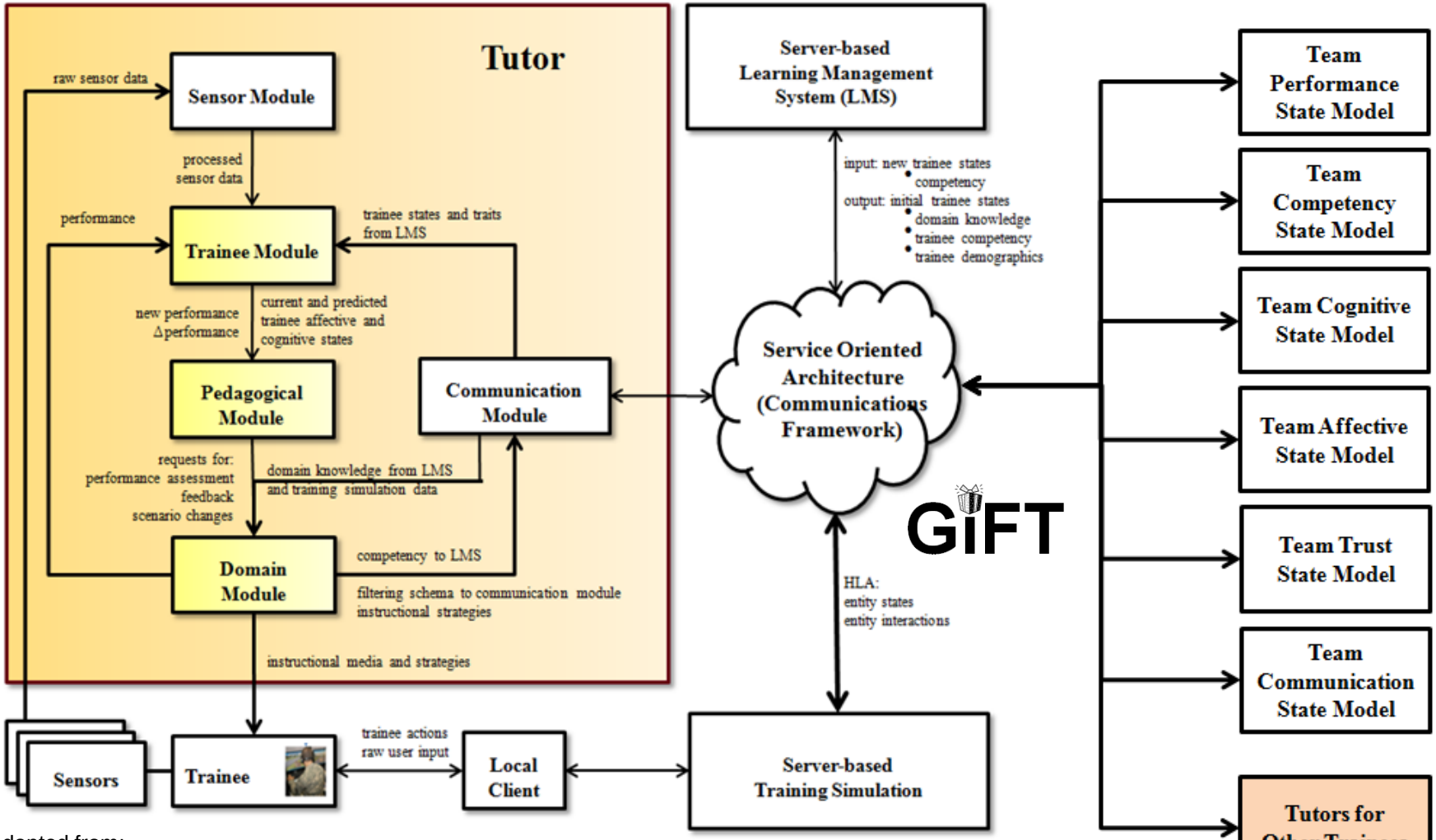
σ	**Optimized trainee performance/retention**	2-3 σ	4-5 σ
50%	**Improved strategy selection accuracy [%]**	90%	→ 100%



A Computer-Based Tutoring Model



A Team Tutoring Model



Adapted from:

Beck, J., Stern, M., and Haugsjaa, E. (1996) Applications of AI in Education, *ACM Crossroads* 3(1), 11-15.

Sottilare, R. (2010). Toward the Development of an Intelligent Tutoring System for Distributed Team Training through Passive Sensing. In V. Aleven, J. Kay, & J. Mostow (Eds.), Proceedings of the 10th International Conference on Intelligent Tutoring Systems (ITS '10), LNCS (Vol. 6095, pp. 411-413). Berlin: Springer.

Bob's Vision for Mobile Tutoring 2025

Conceptual → Practical → Ubiquitous

- **personalized learning** for **individuals and teams**
  - as common as smart phones are today
  - low-cost, distributed, portable, passive sensing
  - natural interaction available via small interface package
    - **glasses** – 3-D visual and aural stimulation; communications; eye tracking; mixed reality; natural language interaction
    - **gloves** – behavioral and physiological measures; haptic feedback
- **accelerated learning and facilitated retention** through:
  - tailored learner modeling
  - efficient, adaptive and challenging pedagogy
- **learning framework** to support:
  - rapid content and model development
  - concept evaluation
  - practice, training, education
  - decision-making in operational contexts
  - ***standard measures of tutor capabilities and effectiveness***

Platinum Tutors

- **adapt to the learner better than a human tutor**
- **enable learning better than a human tutor**
- **fully perceive learner behaviors and physiology through remote sensing**
- **support fully mobile training**
- **are consistently accurate (near 100%) in classifying the learner's cognitive/affective state in near real-time**
- **have an optimized repertoire of instructional strategies**
- **are automatically integrated with a variety of training platforms (e.g., serious games, commercial/military training simulations).**

Sottilare, R. and Gilbert, S. (2011). Considerations for tutoring, cognitive modeling, authoring and interaction design in serious games. Authoring Simulation and Game-based Intelligent Tutoring workshop at the *Artificial Intelligence in Education Conference (AIED) 2011*, Auckland, New Zealand, June 2011.